A New Equation of State for Argon Covering the Fluid Region for Temperatures from the Melting Line to 700 K at Pressures up to 1000 MPa

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A new equation of state for argon is presented. The formulation is in the form of a fundamental equation explicit in the reduced Helmholtz free energy and is valid for single-phase and saturation states from the melting line to 700 K at pressures up to 1000 MPa. A large part of this region is covered by very accurate $p \rho T$ data measured in our group with the two-sinker densitometer and the single-sinker densitometer and by extremely precise speed of sound data measured with spherical resonators. When using the existing state-of-the-art procedures to develop an optimized mathematical structure of such a formulation, it was not possible to find an equation which was able to represent the two data types within their small experimental uncertainty. The representation of these very precise data within their uncertainty could only be achieved by using a specially developed nonlinear regression analysis for optimizing the final functional form of the new equation of state. The formulation contains 41 coefficients, which were fitted to selected experimental data of the following properties: thermal properties of the single phase $(p\rho T)$ and on the vapor-liquid saturation curve $(p_s \rho' \rho'' T)$, speed of sound w, isochoric heat capacity c_v second and third thermal virial coefficients B and C and second acoustic virial coefficients β_a . Comparisons between experimental data and values calculated from the new fundamental equation are given to verify the accuracy of the formulation. The most accurate data of the density and speed of sound are represented within the following uncertainties. For the density, the estimated uncertainty is less than \pm 0.02 % for temperatures between 84 K and 340 K at pressures up to 12 MPa and less than \pm 0.03 % for temperatures between 235 K and 520 K at pressures up to 30 MPa. For the speed of sound, in the region with densities up to half the critical density and temperatures between 90 K and 450 K the estimated uncertainty is, in almost all cases, less than ± 0.02 %. The new formulation shows reasonable thermodynamic behaviour even outside the fitting range at very high pressures and temperatures. Separate equations were developed for the saturated vapor and liquid densities and the pressure on the melting and sublimation curves.